TRACE ELEMENTS IN BASALTIC FRAGMENTS FROM LUNA 16 SOILS. K. C. Welten[1], D. J. Lindstrom[1] and R. R. Martinez[2]. [1]SN4, Johnson Space Center, Houston, TX 77058, [2]Lockheed Martin, 2400 NASA Rd. 1, Houston, TX 77058.

Aluminous mare basalts are the dominant lithology at the Luna 16 landing site in Mare Fecunditatis [1]. Luna 16 basalts typically have high Al_2O_3 contents (>13%), low CaO/Al_2O_3 ratios (<0.9) and low Mg/(Mg+Fe) ratios (*mg'* = 0.3-0.4) compared to most other mare basalts [2,3]. Their bulk compositions suggest they are distinct from other mare basalts, as is supported by the trace element data, although these are relatively scarce for Luna 16 basalts. For trace element analysis by micro-INAA techniques [5], we selected 23 of the 52 Luna 16 basaltic soil fragments studied by [4] and used a micro-coring technique to extract microgram-sized samples from grain mount thin sections. Microprobe analyses suggest that most fragments are typical Luna 16 aluminous mare basalts, whereas one is a very-low-Ti (VLT) basalt. Fifteen fragments have bow-shaped REE patterns similar to those observed in much larger mg-sized Luna 16 fragments [2,6]. Five other fragments are probably related to the main group Luna 16 basalts, but are either enriched in Ba, LREE, Ta, U and Th or up to a factor of 2-3 more enriched in all REE and incompatible trace elements (ITE). Trace element abundances show that three fragments are clearly different from the main group Luna 16 basalts: two samples show almost flat REE patterns and are about a factor of two lower in REE, whereas the third sample is similar in all trace elements to Apollo 17 VLT's. Apparently, this grain has been transported from Mare Serenitatis.

Sampling and Analytical Methods. Five polished thin sections of Luna 16 soil in the size ranges of 250-425 µm (sections SAO 301, 302, 303, 312) and of 125-250 µm (SAO 313) were studied in this work. Microprobe analyses were carried out on 25 of the 52 basaltic fragments described in [4], both for comparison with previous analyses and for normalization of abundances from INAA. Bulk compositions were estimated from a total of 550 microprobe analyses using a Cameca SX-100 microprobe and a typical raster-size of 25x25 µm. Comparison of the estimated bulk compositions of 9 fragments with the averages of [4] show reasonable agreement for most elements except for two relatively coarse-grained fragments. The comparison for FeO suggests a precision of about 5% for fine-grained particles and of 5-10% for coarser-grained particles.

From regular (30 µm) thin-sections, a total of 23 samples ranging in diameter from 140-400 µm were drilled with a micro-coring device mounted on a petrographic microscope: 22 samples of aluminous mare basalts and one VLT basalt fragment. Samples and multiple glass standards were irradiated with 2.3×10^{20} neutrons/cm^2 in the High Flux Beam Reactor at Brookhaven National Laboratory. Subsequent gamma-ray spectroscopy was done using large intrinsic Ge detectors in the low-background counting facility at JSC [5]. The masses of the samples (0.4-8.0 µg) were estimated from the microprobe average of the FeO concentrations and the INAA data for the total amount of FeO in each sample. The absolute uncertainty in the FeO content and thus in all INAA abundances is estimated at 5-10%, although abundance ratios are usually much better known.

Major elements. The microprobe results show a subdivision into two sub-groups (Fig. 1): the main group (I) is composed of 17 fragments with Al_2O_3 contents between 13-17%, MgO contents between 3-7% and low Mg/Fe ratios (*mg'* = 0.30-0.40), similar to the compositions of mg-sized aluminous basalt fragments [2,6]. Three more fragments probably also belong to group I, but show Al_2O_3 contents of 19-21% due to higher amounts of plagioclase.

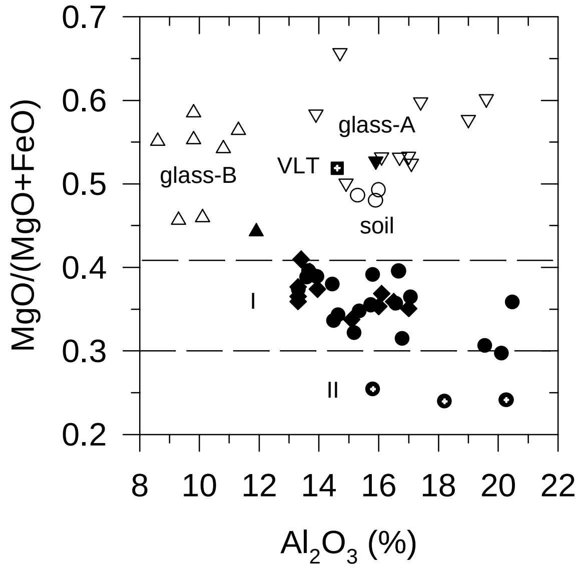

Fig. 1. Major element abundances of Luna 16 basalts. Closed circles are from this work, closed diamonds represent literature values of mg-sized lithic fragments [2]. Open circles represent Luna 16 soil compositions, open triangles 'pristine' glasses [8]. Average compositions of glass-A and glass-B are indicated by closed triangles [7].

Microprobe averages confirm that the compositions of the basaltic fragments are not identical to those of two different types of Luna 16 glasses [4], although the most Mg-rich and Al-poor fragments overlap with the compositions of the Fecunditatis B glasses [7,8]. A second group (II) contains three samples with Al_2O_3 contents between 15-21%, MgO contents between 2-4% and significantly lower *mg'* values (0.24-0.26) than group A. In addition, there is one sample (313-15) with a high MgO content (9%) and a *mg'* value of 0.52. Although most of its major element abundances overlap with those of Fecunditatis A glasses, its very low TiO_2 content (0.4%) suggests an affinity to Apollo 17 VLT basalts.

INAA results. Fifteen of the fragments from Group A show La abundances of 40-80 x CI, small negative Eu anomalies and La/Yb ratios between 1.9-2.3 (Fig. 2). Their REE patterns and other trace element abundances are similar to those of the mg-sized Luna 16 basalts analyzed previously (Fig. 3.) [2,6,9,10].

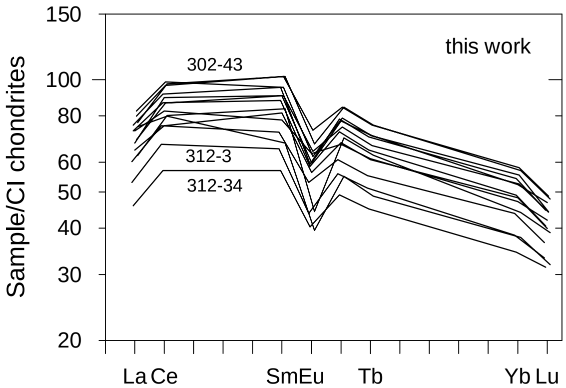

Fig. 2. CI-normalized REE abundances of main group of fifteen µg-sized Luna 16 aluminous basalts studied in this work. All samples show REE abundances within a factor of two and La/Yb ratios between 1.9-2.3.

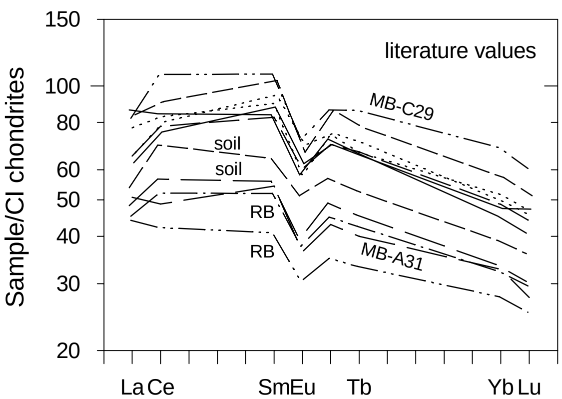

Fig. 3. CI-normalized REE abundances of mg-sized Luna 16 basaltic fragments (MB), breccias (RB) and soil. Basaltic fragments include MB-C29, MB-A31 [9] and the six lines which plot in between the REE patterns of Luna 16 soil and that of MB-C29 [6,10].

Five other samples seem closely related to the main group of Luna 16 basalts, but show some differences in trace element composition: two samples (303-22 and 312-5) are enriched in LREE (and Ta, U and Th), resulting in a steeper slope of the REE pattern. Three other fragments - belonging to group II - show REE patterns parallel to those of group I, but are up to a factor of two enriched in REE (Fig. 4) and in all ITE's. Their major element compositions suggest they might be derived from the main group basalts by fractional crystallization of olivine, but the trace element compositions seem to rule this out. Two other samples are about a factor of two lower in REE and show almost flat REE patterns. In addition, they are depleted in Na, Sr and Sm, which suggest they formed from a source magma which is less rich in plagioclase than the main group of Luna 16 basalts. The single VLT fragment shows a REE pattern typical of the Apollo 17 VLT basalts. Its trace element concentrations suggest that it is related to the MeCo VLT basaltic glasses [11] and was probably transported from Mare Serenitatis by large impacts.

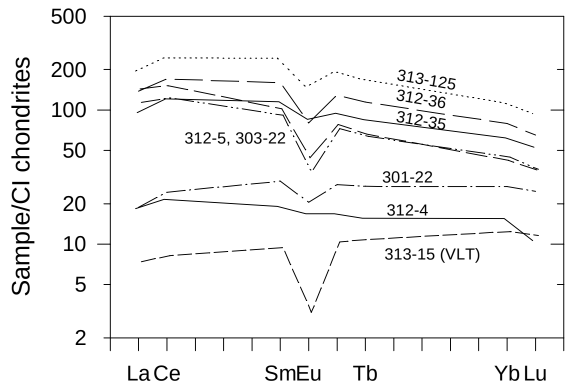

Fig. 4. CI normalized REE abundances of eight µg-sized Luna 16 fragments. The upper three samples (312-35/36 and 313-125) belong to group II. Two LREE enriched fragments (312-5 and 303-22) and two REE depleted samples (301-22 and 312-4) were initially classified as group I basalts. One sample (313-15) shows REE abundances similar to Apollo 17 VLT basalts.

References

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